

# Diet of *Coryphaena hippurus* (Coryphaenidae) associated with FADs in the Ionian and Southern Tyrrhenian Seas

by

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**ABSTRACT.** - The stomach contents of 300 dolphinfish *Coryphaena hippurus* caught in the FAD fishery off North-East and South-East Sicily (central Mediterranean) were analyzed to study the natural diet of this species. Dolphinfish were collected from August 1994 to January 1995 and from July 1995 to November 1995, and included individuals of 0+ age group (11.0-72.5 cm SL). Juvenile teleosts were by far the dominant prey item by frequency of occurrence and by number, irrespective of the area concerned and of predator size and sex. In a limited number of cases only, the numerical percentage of crustaceans was higher than teleosts. Differences in the diet were recorded according to size, sex, and area of collection. Only one prey item (juvenile *Balistes carolinensis*) is a typical component of the FAD assemblage.

**RÉSUMÉ.** - Régime alimentaire de *Coryphaena hippurus* (Coryphaenidae) associés aux DCP dans les mers Ionienne et Tyrrhénienne méridionale.

Les contenus stomacaux de 300 dorades coryphènes *Coryphaena hippurus* capturées dans la pêche commerciale sous les dispositifs de concentration de poissons (DCP) en Sicile nord-est et sud-est (Méditerranée centrale) ont été analysés pour étudier le régime alimentaire de cette espèce. Les individus ont été capturés d'août 1994 à janvier 1995 et de juillet 1995 à novembre 1995 ; ils comprenaient des poissons d'âge 0+ (11,0-72,5 cm LS). Les poissons juvéniles étaient la proie dominante en fréquence d'occurrence et en nombre, sans distinction entre les aires d'étude, ni les tailles ou les sexes des prédateurs. Dans certains cas seulement, le pourcentage en nombre de crustacés a été supérieur à celui des poissons. Des différences dans le régime alimentaire ont été trouvées en fonction de la taille, de la zone d'étude et du sexe des dorades coryphènes. Seulement une proie (*Balistes carolinensis* juvénile), caractéristique des communautés de DCP, a été retrouvée dans les estomacs analysés.

Key words. - Coryphaenidae - *Coryphaena hippurus* - MED - Sicily - Diet - Feeding habits - FADs.

Dolphinfish *Coryphaena hippurus* L., 1758 is an epipelagic species occurring worldwide in tropical and subtropical seas (Collette, 1986). In the Mediterranean Sea, adult specimens are occasionally caught with drifting long-lines or trolling lines. From midsummer to late autumn or early winter, juveniles up to about 70 cm total length are the target of offshore local fishermen, especially around the Balearic Islands, Tunisia, Sicily and Maltese Islands (Massutí and Morales-Nin, 1995; Potoschi *et al.*, 1999; Vella, 1999; Zaouali and Missaoui, 1999). Since dolphinfish are well-known for their association with flotsam, Mediterranean fishermen use FADs (Fish Aggregation Devices) moored offshore to aggregate shoals, which are then caught with surrounding nets.

Dolphinfish occur with other fish species below flotsam and are the dominant component of this particular epipelagic assemblage (Andaloro *et al.*, 2003; Massutí and Reñones, 1994). Unlike what can be recorded for the Atlantic and the Pacific oceans, feeding-related habits of dolphinfish in the

Mediterranean have not been the object of thorough research. Its diet, as well as its trophic relationships with other FAD associated fish, was studied extensively in Majorcan waters (Massutí *et al.*, 1998; Deudero, 2001) while few observations were reported from Malta (Bannister, 1976). In both areas, juvenile dolphinfish are depicted as mainly piscivore predators and, in Majorcan waters, this species experiences significant changes in diet during growth. In trophic terms, *C. hippurus* is a top predator in the pelagic ecosystem (Massutí *et al.*, 1998), and fishing activities may provoke top-down consequences on pelagic food resources. The knowledge of trophic webs within this assemblage is still very limited (Deudero, 2001; Andaloro *et al.*, 2003), and new insight on this topic can provide useful ecological information, which can also be exploited for an ecosystem approach to pelagic fishery management.

Due to the extremely diverse prey array found in the stomachs of dolphinfish from different parts of the world, and to the varying trends in food preference according to

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season and geographic location (Palko *et al.*, 1982; Manooch *et al.*, 1984; Taquet, 2004), new studies, such as this one, may contribute to the knowledge of the ecology and biology of this species. The present paper describes the results of a study carried out on the diet of dolphinfish associated with FADs in two areas of the central Mediterranean, where FAD fisheries are well developed (Potoschi and Sturiale, 1996).

## MATERIAL AND METHODS

Dolphinfish were sampled in the early morning hours, between 06:00 and 09:00, from August 1994 to January 1995 and from July 1995 to November 1995, aboard commercial boats of the FAD fishery off the coasts North-East and South-East Sicily (approximately 38°20'N-14°30'E and 36°30'N-15°20'E; Fig. 1), in the Tyrrhenian and Ionian Sea, respectively.

Each specimen was eviscerated immediately after the catch. Sex was macroscopically determined by visual inspection of gonads. Stomachs were preserved in 10% seawater-formalin solution, then dissected in the laboratory, and the contents were identified to the lowest possible taxonomic level. The vacuity coefficient (V% = percent of empty stomachs) was calculated, as well as the percentage of frequency of occurrence in non-empty stomachs (F%) and the numerical percentage (N%) of each food item. Weight percentage (W%) and the index of relative importance (IRI% in weight, Sabatié *et al.*, 2003) were calculated for 8 grouped prey categories as follows: fish, crustaceans, cephalopods, appendicularians, pelagic gastropods, siphonophorans, vegetal remains, unidentified organisms.

In order to detect differences in food preference accord-

ing to predator size, dolphinfish of each area were grouped in three size classes (group I:  $\leq 30$  cm; group II: 30-40 cm; group III:  $> 40$  cm).

IRI% computed for grouped prey categories was then used to compare data between study areas, in each size class and sex. For the analysis by sex, only specimens with clearly differentiated gonads were considered.

Non parametric multivariate analysis of variance (NPMANOVA) (Anderson, 2000) was applied on both prey abundance and prey weight. This analysis was first computed to detect differences between areas; when significant differences were detected ( $p < 0.05$ ), NPMANOVA was repeated within each study area in order to detect differences between size classes and between sexes. Data were transformed to  $\ln(x+1)$ ; this analysis is based on Gower distances. Pair-wise *a posteriori* comparisons were computed after significant differences among factor levels were detected.

## RESULTS

A total of 132 dolphinfish from the Ionian Sea and 168 from the Tyrrhenian Sea, ranging from 11.0 to 72.5 cm standard length (SL) (average SL =  $37.9 \pm 9.5$ ) and corresponding to the 0+ age group (Massuti *et al.*, 1999), were collected: 162 female specimens (11.0-69.0 cm SL) and 138 male specimens (16.5-72.5 cm SL).

Teleosts (mostly post-larvae or early juveniles) occurred in 87.6% of the 258 non-empty stomachs, attaining a numerical percentage of 47.6% (15 items per stomach on average), and accounting for a weight percentage of 90.6% of total weight. 26 families were identified: myctophids, sparids and engraulids occurred most frequently (F% = 15.1, 14.3 and 13.2, respectively). Teleosts were generally present at a highly digested degree and as unidentifiable remains, which account for the high percentage of unidentified fish among prey items.

Crustaceans occurred in 56.2% of non-empty stomachs. Although a relatively large number was detected (N% = 44.4), their weight only accounted for 5.8% of total weight. Hyperiid amphipods were the dominant group among crustaceans (F% = 36.0, N% = 24.4), followed by stomatopod larvae, euphausiids and decapod larvae.

Cephalopods gave a smaller contribution to the overall diet (F% = 16.3, N% = 0.8, W% = 3.2) as well as appendicularians, siphonophorans and pelagic gastropods.

## NPMANOVA

The analysis of the diet according to the number (N) and weight (W) of grouped prey categories led to highlight significant differences ( $p < 0.01$ ) between areas ( $F_{(N)1,224} = 12.343$ ;  $F_{(W)1,224} = 6.462$ ), non significant differences

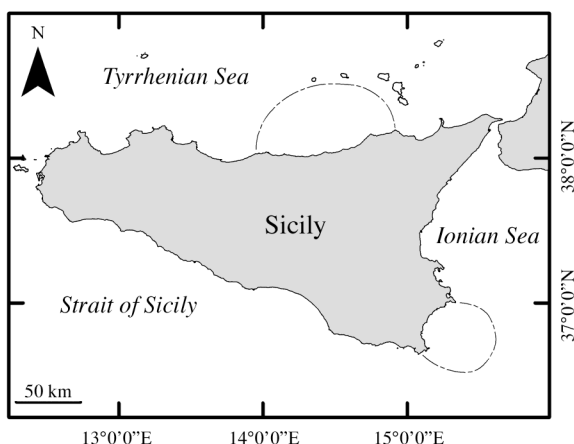


Figure 1. - Map of the study area. Dashed line delimits the FAD fishery areas. [Carte de la zone étudiée indiquant les aires de pêche sous DCP (en pointillé).]

between Ionian males and females, non significant differences in prey abundance, significant differences in prey weight between Tyrrhenian males and females ( $F_{(W)1,112} = 4.685$ ). Non significant differences were also recorded among Ionian size classes, while significant differences ( $p < 0.01$ ) were highlighted among Tyrrhenian size classes both as regards prey abundance ( $F_{(N)2,102} = 5.519$ ) and prey weight ( $F_{(W)2,102} = 6.067$ ) with pair-wise *a posteriori* comparisons in both cases resulting as group I = group II < group III.

Based on the results of the NPMANOVA, stomach contents data were examined separately according to area, sex and size group.

### Variation by area

The results of the stomach content analysis of dolphinfish in each study area are shown in table I. The vacuity index was  $V\% = 14$  in both areas. Teleosts were the favourite food of dolphinfish caught in the Ionian Sea; the most frequent fish were engraulids, which occurred in 20.4% of stomachs and accounted for 65.6% in number; sparids, myctophids, argentinids and clupeids were less frequent. The presence of crustaceans was also significant in terms of F% (46.0), although they represented a very small portion when it comes to weight ( $W\% = 3.1$ ). In the Tyrrhenian Sea, teleosts were the most important prey in terms of F% and W%; myctophids were the most frequent family ( $F\% = 20.0$ ), followed by sparids ( $F\% = 17.9$ ) and exocoetids ( $F\% = 11.0$ ); these families were also the most abundant ( $N\% = 26.0, 36.9$  and  $17.5$  respectively). Crustaceans (with a large contribution of hyperiids) were the most abundant prey overall ( $N\% = 63.9$ ), but represented only 8.2% in weight. Cephalopods were of secondary importance, occurring in only 25.5% of the stomachs. Figure 2 synthesizes F%, N% and W% for major prey categories in dolphinfish from the two study areas.

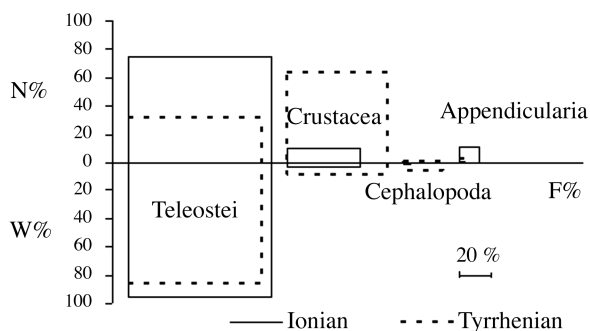


Figure 2. - Food indexes of dolphinfish (F% = percentage of frequency of occurrence, N% = numerical percentage, W% = weight percentage) in the Ionian and the Tyrrhenian Seas. [Indices alimentaires des dorades coryphènes (F% = pourcentage d'occurrence, N% = pourcentage numérique, W% = pourcentage pondéral) dans les mers Ionienne et Tyrrhénienne.]

### Variation by sex

A few differences were noticed in the food habits of males and females. Teleosts still remained the most important prey in both sexes, but the importance of crustaceans was greater in females rather than in males from both areas (Fig. 3). Cephalopods were also more important in the diet of females (IRI% = 0.2 and 2.0 in Ionian and Tyrrhenian Sea, respectively) than in that of males (IRI% = < 0.1 and 0.6 in Ionian and Tyrrhenian Sea respectively).

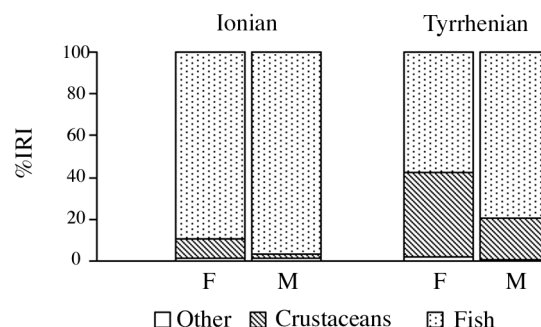


Figure 3. - IRI% of main prey categories of female (F) and male (M) dolphinfish from the Ionian and the Tyrrhenian Seas. [IRI% pour les principales catégories de proies des femelles (F) et des mâles (M) de dorade coryphène des mers Ionienne et Tyrrhénienne.]

### Variation by size

Dolphinfish from the two areas showed a different trend in food partition varying between the three size groups considered in this study (Fig. 4). Teleosts were the most important food item in Ionian specimens, equally represented in the three size groups, while crustaceans occurred in very small quantities; in the Tyrrhenian specimens, crustaceans had a larger role in groups I and II than in group III, which, conversely, showed a net preference for fish prey.

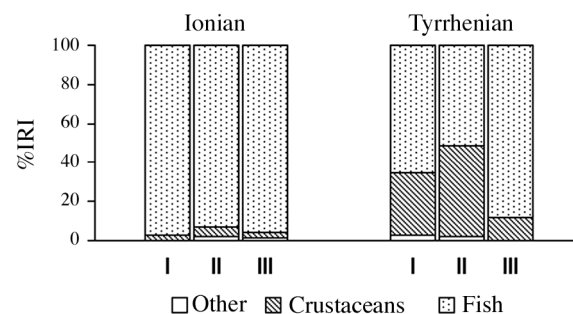


Figure 4. - IRI% of main prey categories in three size groups of dolphinfish from the Ionian and the Tyrrhenian Seas. [IRI% des principales catégories de proies en trois classes de taille de dorade coryphène des mers Ionienne et Tyrrhénienne.]

Table I. - Food indexes calculated for Ionian and Tyrrhenian dolphinfish separately. Prey abundance (N%) and frequency of occurrence (F%) were calculated for each prey item; prey weight (W%) and IRI% were calculated for larger categories only. [Indices alimentaires calculés séparément pour les dorades coryphènes ioniennes et tyrrhéniennes. L'abondance (N%) et l'occurrence (F%) de proies ont été calculées pour chaque catégorie; le poids (W%) et l'IRI% ont été calculés seulement pour les principales catégories.]

Taxa		Ionian Sea				Tyrrhenian Sea			
		N%	F%	W%	IRI%	N%	F%	W%	IRI%
Argentinidae	<i>Glossanodon leioglossus</i>	7.83	7.08			0.13	1.38		
Balistidae	<i>Balistes carolinensis</i>	0.27	3.54			0.06	2.07		
Belonidae	<i>Belone belone</i>	0.13	2.65						
Caproidae	<i>Capros aper</i>					0.04	1.38		
Carangidae	<i>Trachinotus ovatus</i>	0.30	1.77			0.04	1.38		
	Unid. Carangidae	0.03	0.88			0.02	0.69		
Centrolophidae	<i>Schedophilus medusophagus</i>	0.07	1.77			0.04	1.38		
Chauliodontidae	<i>Chauliodus sloanei</i>					0.08	2.76		
Clupeidae	<i>Sardina pilchardus</i>	0.07	1.77			0.02	0.69		
	<i>Sardinella aurita</i>	1.27	2.65						
	Unid. Clupeidae	0.84	3.54			0.17	2.07		
Coryphaenidae	<i>Coryphaena hippurus</i>					0.50	0.69		
Engraulidae	<i>Engraulis encrasicolus</i>	38.83	20.35			5.08	7.59		
Exocoetidae	<i>Cheilopogon heterurus</i>					0.02	0.69		
	<i>Cheilopogon</i> sp.	0.03	0.88			0.15	3.45		
	Unid. Exocoetidae	0.23	3.54			0.25	6.90		
Gadidae	<i>Gadiculus argenteus</i>					0.02	0.69		
Gobiidae	Unid. Gobiidae					0.02	0.69		
Gonostomatidae	<i>Cyclothone</i> sp.	0.03	0.88			0.19	1.38		
	Unid. Gonostomatidae	0.40	0.88			0.17	2.07		
Macrorhamphosidae	<i>Macroramphosus scolopax</i>					0.06	2.07		
Myctophidae	<i>Benthoema glaciale</i>	0.03	0.88			0.13	0.69		
	<i>Ceratoscopelus maderensis</i>	0.07	0.88			0.13	2.76		
	<i>Electrona rissoi</i>					0.02	0.69		
	<i>Hygophum benoiti</i>					0.04	0.69		
	<i>Lampanyctus pusillus</i>					0.12	1.38		
	<i>Lampanyctus</i> sp.					0.21	0.69		
	<i>Notoscopelus elongatus</i>	0.13	0.88			0.04	0.69		
	Unid. Myctophidae	1.81	7.08			2.73	15.17		
Paralepididae	<i>Paralepis coregonoides</i>	0.17	2.65			0.04	1.38		
	<i>Paralepis speciosa</i>					0.15	1.38		
	<i>Paralepis</i> sp.	0.10	1.77			0.19	1.38		
	Unid. Paralepididae	0.17	2.65			0.12	1.38		
Photichthyidae	<i>Vinciguerrria attenuata</i>					0.04	0.69		
	<i>Vinciguerrria</i> sp.	0.33	2.65			0.15	2.76		
Scomberesocidae	<i>Scomberesox saurus</i>	0.64	3.54			0.31	6.21		
Scombridae	Unid. Scombridae	0.07	0.88			0.08	2.07		
Serranidae	<i>Anthias anthias</i>					0.06	2.07		
	<i>Callanthias ruber</i>					0.02	0.69		
Sparidae	<i>Pagellus bogaraveo</i>	0.90	0.88			4.01	4.83		
	<i>Pagellus</i> sp.	3.41	6.19			3.00	11.03		
	Unid. Sparidae	0.94	2.65			0.21	2.76		
Syngnathidae	<i>Nerophis</i> sp.	0.07	0.88						
	Unid. Syngnathidae	0.03	0.88						
Tetragonuridae	<i>Tetragonurus cuvieri</i>					0.64	1.38		
Trichiuridae	<i>Lepidopus caudatus</i>					0.02	0.69		
Uranoscopidae	<i>Uranoscopus scaber</i>	0.03	0.88			0.02	0.69		
Unid. teleost		15.79	61.95			12.25	45.52		
Total teleosts		75.0	91.2	95.6	95.2	31.8	84.8	86.0	67.5

Table I. - Continued. [Suite.]

Taxa		Ionian Sea				Tyrrhenian Sea			
		N%	F%	W%	IRI%	N%	F%	W%	IRI%
Copepoda	Calanoida	0.03	0.88						
Decapoda	Brachyura larvae	0.10	2.65			0.06	0.69		
	Palaemonidae mysids					0.17	2.76		
	Decapoda larvae	1.84	13.27			1.60	14.48		
	<i>Pasiphaea multidentata</i>	0.03	0.88						
	Unid. Natantia	0.03	0.88			0.44	6.90		
Euphausiacea		0.10	2.65			16.97	28.97		
Amphipoda	Hyperidea	3.98	19.47			36.20	48.97		
Isopoda	<i>Idotea metallica</i>	0.07	0.88			0.75	11.03		
Stomatopoda	Stomatopoda larvae	3.14	17.70			2.98	33.10		
Unid. crustaceans		1.24	4.42			4.74	8.28		
	Total Crustaceans	10.6	46.0	3.1	3.9	63.9	64.1	8.2	31.2
Octopoda	<i>Eledone</i> sp.					0.02	0.69		
Sepioidea	<i>Sepia orbygniana</i>	0.03	0.88						
	Sepiolinae unidentified	0.03	0.88			0.04	1.38		
Teuthoidea	<i>Illex coindetii</i>					0.02	0.69		
	<i>Todarodes sagittatus</i>					0.04	1.38		
	<i>Alloteuthis media</i>					0.04	1.38		
	Teuthoidea unidentified					0.35	9.66		
Unid. Cephalopoda		0.10	2.65			0.71	15.86		
	Total Cephalopods	0.2	4.4	0.6	< 0.1	1.2	25.5	5.7	1.2
Gastropoda	Atlantidae					0.10	2.07	0.00	
Cnidaria	Siphonophora	0.43	0.88	0.01					
Tunicata	Appendicularia	11.27	12.39	0.45	0.9	2.39	6.21	0.09	0.1
Insecta						0.06	2.07		
Vegetal remains		0.20	5.31	0.19		0.02	0.69	0.03	
Unid. contents		2.34	6.19	0.07		0.52	6.21	0.02	

## DISCUSSION

Juvenile dolphinfish caught off the coasts North-East and South-East Sicily are voracious predators whose diet is based to a large extent on fish prey. Overall, the dolphinfish collected fed mostly on early juvenile stages of gregarious fish, as suggested by the high numbers of unidentified fish of approximately the same size that were observed in the stomachs. Some of the identified teleosts were very young pelagic stages of species which are demersal as adults (*Balistes carolinensis*, *Macroramphosus scolopax*), but most of them were juveniles of epipelagic (Exocoetidae, Scomberesocidae) or mesopelagic (Chauliodontidae, Myctophidae, Paralepididae, Trichiuridae) families. The fact of feeding upon mesopelagic teleosts is indicative of energy transfer between the epipelagic and the mesopelagic environments by means of the food web, and remarks the importance of the dolphinfish predatory activity in the whole pelagic system. The dominance of teleosts in the diet of dolphinfish was pointed out in previous studies carried out in oceanic waters (Palko *et al.*, 1982 and references listed therein), as well as in Mediterranean waters (Deudero, 2001). However, our data suggest the great importance of pelagic crustaceans, mostly represented by hyperiids, euphausiids, stomatopod larvae and decapod larvae, in line with the observations of Demp-

ster (2004) in Australian waters and Massutí *et al.* (1998) in the Mediterranean. On the other hand, cephalopods were of minor importance, and categories such as pelagic gastropods and siphonophorans may be considered as occasional food items in the diet of dolphinfish.

Prey importance varied according to the area, as confirmed by the significant differences recorded in prey abundance and weight. In both areas, according to all numeric indicators, dolphinfish rely mainly on fish for their diet. Likewise, pelagic crustaceans (mostly hyperiid amphipods and euphausiids) and cephalopods played a non-negligible role in the diet of Tyrrhenian dolphinfish, while they were of minor importance for the Ionian individuals. The opposite trend was noticed for appendicularians, even though they contributed to a minor extent to the overall diet. This diverse array of prey is likely to be a reflection of different food resource availability in the two areas and would confirm the opportunistic feeding habits of dolphinfish. Furthermore, the importance of crustaceans as a food resource in the Tyrrhenian Sea was also stressed in *Auxis rochei* (Mostarda, 2006), *Euthynnus alletteratus* (Falautano *et al.*, 2007) and juvenile *Thunnus thynnus* (Sinopoli *et al.*, 2004), confirming the availability of such resource in this area.

The low vacuity index recorded in specimens captured in the morning, in both areas, suggests that dolphinfish are

diurnal predators. Yet, the occurrence of mesopelagic teleosts (8.6% of total fish prey, especially myctophids and paralepidids), which undergo vertical upward migrations at night, provide evidence of some nocturnal feeding activity in the dolphinfish, as observed also in other seas (Olson and Galván-Magaña, 2002; Taquet, 2004).

Differences in prey weight were detected between Tyrrhenian males and females, particularly due to the greater importance of crustaceans in the diet of females. This trend was also evidenced for Ionian specimens, although the difference was not significant in this case. This finding is in line with the known behaviour of females, which spend more time around floating objects, while males are more likely to explore wider areas searching for free swimming pelagic prey (Oxenford, 1999).

As a result of rapid changes in body size and of the fast growth of dolphinfish, particularly during its juvenile phase (Oxenford and Hunte, 1983), a diet shift may result in a change of the relative importance of different prey categories. Dolphinfish of larger sizes from the Tyrrhenian showed a higher IRI% teleosts/crustaceans ratio than what was recorded in smaller fish, although no food partition among size groups seemed to occur for Ionian specimens. This remarkably different diet composition between the two areas suggests that food partitioning among size classes may depend more on resource availability than on specific food preference in a given size group. Decreasing importance of crustaceans in bigger size dolphinfish was also recorded in western Mediterranean waters by Massutí *et al.* (1998), who also found a positive trend between cephalopods and predator size. More specifically, Massutí *et al.* (1998) found that cephalopods become important in the diet of dolphinfish that are longer than 60 cm fork length, i.e. in a wider size range than the one examined in our study. Furthermore, their samples included fish caught mainly with long-line: for these reasons, those results are not directly comparable with ours.

Mediterranean dolphinfish do not seem to have any trophic link with the FADs around which they are commonly fished. Similar conclusions were drawn by Sakamoto and Taniguchi (1993) for dolphinfish caught around manmade bamboo FADs ("tsukegi") in Japanese waters, as well as by Taquet (2004) for dolphinfish caught around several types of floating objects in the Indian Ocean. In our study, the only prey species closely associated to FADs was the juvenile triggerfish *B. carolinensis*, which occurred in 2.7% of the stomachs and represented only 0.3% in number of total fish. This suggests that dolphinfish are attracted by FADs owing to factors that are not related to food, and leads to hypothesize that a specific prey selection among fish associated to FADs takes place.

Comparing studies on the feeding habits of dolphinfish

often leads to contrasting results due to differences in geographical or temporal factors, although their generalist behaviour seems to be consistently confirmed. Our results suggest that prey availability should be significant for the diet of dolphinfish, which often rely on epipelagic and mesopelagic prey and only very rarely include FAD-associated species in their prey array. The differences in prey composition between the two areas investigated lead us to consider *Coryphaena hippurus* more as an opportunist than a generalist. The catch of dolphinfish by FAD-based fisheries would interact with the ecology of other pelagic predators like little tunny, bullet tuna, Atlantic bonito, and juvenile bluefin tuna, which also feed on pelagic prey and are the target species of both professional and recreational fisheries in the study areas. For this reason, research on the feeding ecology of interacting species in the pelagic domain must be fostered for the development of fruitful management strategies.

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## REFERENCES

- ANDALORO F., CAMPO D., SINOPOLI M., CASTRIOTA L. & S. CAMPAGNUOLO, 2003. - Pelagic fish community associated with FADs off the Sicilian coast (Southern Tyrrhenian Sea). *In: Island Ecosystems Conservation and Molecular Approach I, Symposium, Madeira Island, Portugal, March 2001* (Pinheiro de Carvalho M.Á.A., Pereira Costa G., Abreu Jesus J. & D.M.M. Rodrigues, eds), pp. 131-138. Madeira: CCBG.
- ANDERSON M.J., 2000. - NPMANOVA: a FORTRAN computer program for non-parametric multivariate analysis of variance (for any two-factor ANOVA design) using permutation tests. Department of Statistics, Univ. of Auckland.
- BANNISTER J.V., 1976. - The length-weight relationship, condition factor and gut contents of the dolphin-fish *Coryphaena hippurus* (L.) in the Mediterranean. *J. Fish Biol.*, 9: 335-338.
- COLLETTE B.B., 1986. - Coryphaenidae. *In: Fishes of the North-Eastern Atlantic and the Mediterranean, II* (Whitehead P.J.P., Bauchot M.-L., Hureau J.-C., Nielsen J. & E. Tortonese, eds), pp. 845-846. Paris: Unesco.
- DEMPSTER T., 2004. - Biology of fish associated with moored fish aggregation devices (FADs): Implications for the development of a FAD fishery in New South Wales, Australia. *Fish. Res.*, 68: 189-201.
- DEUDERO S., 2001. - Interspecific trophic relationships among pelagic fish species underneath FADs. *J. Fish Biol.*, 58: 53-67.
- FALAUTANO M., CASTRIOTA L., FINOIA M.G. & F. ANDALORO, 2007. - Feeding ecology of little tunny *Euthynnus alletteratus* in the Central Mediterranean Sea. *J. Mar. Biol. Ass. U.K.*, 87: 999-1005.
- MANOOCH C.S. III, MASON D.L. & R.S. NELSON, 1984. - Food and gastrointestinal parasites of dolphin *Coryphaena hippurus* collected along the southeastern and gulf coasts of the United States. *Bull. Jpn. Soc. Sci. Fish.*, 50: 1511-1525.

- MASSUTÍ E. & O. REÑONES, 1994. - Observaciones sobre la comunidad de peces pelágicos asociados a objetos flotantes en aguas oceánicas de Mallorca. *Bol. Inst. Esp. Oceanogr.*, 10: 81-93.
- MASSUTÍ E. & B. MORALES-NIN, 1995. - Seasonality and reproduction of dolphin-fish (*Coryphaena hippurus*) in the western Mediterranean. *Sci. Mar.*, 59: 357-364.
- MASSUTÍ E., DEUDERO S., SANCHEZ P. & B. MORALES-NIN, 1998. - Diet feeding of dolphin (*Coryphaena hippurus*) in Western Mediterranean waters. *Bull. Mar. Sci.*, 63: 329-341.
- MASSUTÍ E., MORALES-NIN B. & J. MORANTE, 1999. - Otolith microstructure, age, and growth patterns of dolphin, *Coryphaena hippurus*, in the western Mediterranean. *Fish. Bull.*, 97: 891-899.
- MOSTARDA E., 2006. - Feeding ecology of the bullet tuna (*Auxis rochei*) and the Atlantic bonito (*Sarda sarda*) in the southern Tyrrhenian Sea. PhD thesis, 144 p. Univ. of Rome "La Sapienza", Italy.
- OLSON R.J. & F. GALVÁN-MAGAÑA, 2002. - Food habits and consumption rates of common dolphinfish (*Coryphaena hippurus*) in the eastern Pacific Ocean. *Fish. Bull.*, 100: 279-298.
- OXENFORD H.A., 1999. - Feeding habits of the dolphinfish (*Coryphaena hippurus*) in the eastern Caribbean. *Sci. Mar.*, 63: 303-315.
- OXENFORD H.A. & W. HUNTE, 1983. - Age and growth of dolphin, *Coryphaena hippurus*, as determined by growth rings in otoliths. *Fish. Bull.*, 84: 906-909.
- PALKO B.J., BEARDSLEY G.L. & W.J. RICHARDS, 1982. - Synopsis of the biological data on dolphin-fishes, *Coryphaena hippurus* Linnaeus and *Coryphaena equiselis* Linnaeus. *FAO Fish. Synop.*, 130: 1-28.
- POTOSCHI A. & P. STURIALE, 1996. - Distribuzione dei "cannizzi" nel Tirreno meridionale e nello Ionio per la cattura della lampuga *Coryphaena hippurus* L., 1758. *Biol. Mar. Medit.*, 3: 384-386.
- POTOSCHI A., CANNIZZARO L., MILAZZO A., SCALISI M. & G. BONO, 1999. - Sicilian dolphinfish (*Coryphaena hippurus*) fishery. *Sci. Mar.*, 63: 439-445.
- SABATIÉ R., POTIER M., BROUDIN C., SÉRET B., MÉNARD F. & F. MARSAC, 2003. - Preliminary analysis of some pelagic fish diet in the Eastern Central Atlantic. *Col. Vol. Sci. Pap. ICCAT*, 55: 292-302.
- SAKAMOTO R. & N. TANIGUCHI, 1993. - Stomach contents of dolphinfish, *Coryphaena hippurus*, caught around bamboo rafts in Tosa Bay, the waters southwestern Japan. *Bull. Jpn. Soc. Fish. Oceanogr. Suisan Kaiyo Kenkyu*, 57: 17-29.
- SINOPOLI M., PIPITONE C., CAMPAGNUOLO S., CAMPO D., CASTRIOTA L., MOSTARDA E. & F. ANDALORO, 2004. - Diet of young-of-the-year bluefin tuna, *Thunnus thynnus* (Linnaeus, 1758), in the southern Tyrrhenian (Mediterranean) Sea. *J. Appl. Ichthyol.*, 20: 310-313.
- TAQUET M., 2004. - Le comportement agrégatif de la dorade coryphène (*Coryphaena hippurus*) autour des objets flottants. Thèse de doctorat, 168 p. Univ. de Paris 6, Océanologie biologique, Editions Ifremer.
- VELLA A., 1999. - Dolphinfish fishery around the Maltese Islands. *Sci. Mar.*, 63: 465-467.
- ZAOUALI J. & H. MISSAOUI, 1999. - Small-scale Tunisian fishery for dolphinfish. *Sci. Mar.*, 63: 469-472.

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